Rooftop rainwater management - a key to resolve water crisis in India

La gestion des eaux pluviales de toiture : une clé pour résoudre la crise de l’eau en Inde

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RÉSUMÉ
La surexploitation des nappes phréatiques de New Delhi a dépassé leur recharge. Depuis le 31 décembre 2001, le gouvernement indien a rendu obligatoire la collecte des eaux de toiture. Pour la mise en place de ce plan, nous avons sélectionné une maison occupée par 6 adultes à Pratapganj, à l’est de Delhi, sur un terrain de 900 m², avec une toiture d’une surface de 150 m². Par rapport au puits situé dans la maison, la nappe phréatique de Pratapganj se trouve à 5,5 m de profondeur, à 7 m en période sèche. L’expérience qui s’est déroulée entre les mois de juin et août 2003 nous a permis d’observer que le niveau d’eau dans le puits augmente au mois de septembre. L’eau de toiture récoltée est acheminée vers le puits à l’aide d’un tuyau de 10 cm de diamètre, alimentant ainsi la nappe phréatique. Cette technique de récolte des eaux de toiture est la plus adaptée dans cette région de l’Inde où l’urbanisation a diminué l’espace disponible.

ABSTRACT
The over exploitation of ground water in New Delhi exceeded the recharge. Since 31st December 2001, Government of India made the roof-top rain water harvesting mandatory. A dwelling unit with a roof top area of 150 m² in a total land area of 900 sq. m. in Pratapganj in East Delhi where six adult persons reside was selected for the implementation of the scheme of roof-top rain water conservation. The water table in Pratapganj is found to be at 5.5m in the hand pump of the dwelling unit which goes further down to about 7.0 m during dry season. The project was implemented from the month of June to August 2003, and it was observed that the water level has risen in the month of September. The collected roof-top rain water is channeled through 10 cm diameter pipe to the existing bore hole to recharge the aquifer. This technique of roof-top rain water harvesting has been found the most appropriate in this area because not much of land is available due to increased urban activities.

KEYWORDS
Water scarcity, Recharge, Groundwater, Borehole, Water level
1 INTRODUCTION

Concern over ensuring safe drinking water supply to every citizen in the next 20 years, seems to have finally caught up with everyone in the country. It is estimated that the current annual demand for 552 billion cubic meters (BCM) of water across the country will shoot up to 1050 BCM in 2050. The present water supply coverage and its availability/day in four metros is; Kolkata 66% for 10 hrs/day; Chennai 97% for 4 hrs/day; Delhi 86% for 3.5 hrs/day and Mumbai 100% for 5 hrs/day. Urban centers in India especially, the metropolitan cities like New Delhi, Mumbai, Chennai and Kolkata are facing an ironical situation today. On one hand there is the acute water scarcity and on the other, the streets are often flooded with storm water during the monsoons. This has led to serious problems with quality and quantity of groundwater. With annual water bodies drying up due to over exploitation of under groundwater resources, urban areas are suffering from inequitable water distribution and mismanagement of supply, especially Delhi where despite the fact that it receives good rainfall but this rainfall occurs during short spells of high intensity (Most of the rain falls in just 100 hours out of 8,760 hours in a year). Because of such short duration of heavy rain, most of the rain falling on the surface tends to flow away rapidly leaving very little for recharge of groundwater. One of the solutions to Delhi water crisis is rainwater harvesting - capturing the storm water runoff. The following shows that in many parts of Delhi including the study area, increasing population and limited water resources require more storage of water for potable purposes.

2 WHY ROOF-TOP RAIN WATER HARVESTING?

* In areas where there is inadequate groundwater supply or surface resources are either lacking or insufficient, rainwater harvesting offers an ideal solution.

* Helps in utilizing the primary source of water and prevent the runoff from going into sewer or storm drains, thereby reducing the load on treatment plants.

* Reduces urban flooding.

* Recharging water into the aquifers help in improving the quality of existing groundwater through dilution.

3 STORM WATER MANAGEMENT

In view to supporting the present generation and saving the future one from the grip of acute water
shortage, the “Roof-Top Rain Water Harvesting” to conserve water where it falls has successfully been implemented with the following scheme to recharge the aquifer artificially during monsoon in Pratapganj, the eastern part of New Delhi in the year 2000 where natural recharge was very low due to urbanization and the water table registered continuous decline. As the recharge in the area is considerably reduced due to increased urban activities and not much of land is available for implementing any other artificial recharge measure.  

The reasons for decline in ground water levels are:

1. Rapid pace of urbanization, leading to reduction in recharge of aquifers.
2. Increasing demand in agriculture and industrial sectors as well as domestic needs for the ever growing population.
3. Stress laid on ground water extraction during drought periods when all other sources shrink.
4. Unplanned withdrawal from subsoil aquifer.

The storm water management for the excess rainwater that flows from rooftops, roads and other buildings is applied in a dwelling unit in Pratapganj area in East Delhi in 2006 with the objectives to maintain and augment natural groundwater as an economic resource and to conserve excess surface water underground as the withdrawal of under groundwater is more than the rate of recharge creating an imbalance in the groundwater reserves. A storm water harvesting system comprises components of various stages - transporting rainwater through pipes, filtration, and storage in tanks for recharging the aquifer through hand pump is applied successfully which not only recharged the aquifer and improved the quality of the under groundwater through dilution but also prevented the surface runoff from going into storm drains thus, reducing the urban flooding.

FIG 1. Colossal waste of storm water on Pratapganj roads

4 GEOLOGICAL SETTING

Geologically, the entire city of Delhi lies on the Indo-Gangetic plains comprising undisturbed layers of geologically recent sediments. it is an aggradational plain, entirely build up of thick alluvium which the Himalayan streams and rivers have brought down during their mountainous courses and have deposited it where they enter the plains. the city of Delhi is one such area. the thickness of overlying alluvial fill consists of sand, silt and clay in the city is fairly uniform. on the eastern side, the city is flanked by the river Yamuna. along the river, a maximum concentration of groundwater extraction structures constitute the Yamuna well field which is exploited for drinking water supply to east Delhi township. The soils of the Delhi area are mostly light with subordinate amount of medium texture soils.  The light texture soils are represented by sandy, loamy, sand and sandy loam; whereas medium texture soils are represented by loam silty loam. The first sand formation exists up to a depth of 20m below ground level, which is followed by impermeable layer of clay and silt which extents from depth of 20 to 28m below ground level. A comparative study of water level map of 1960 and 2002 shows the water level which was at 0 to 2m below ground level has now gone down to 5 to 10m below ground
level. The ground water availability in the territory is controlled by the hydrogeological situation characterized by occurrence of alluvial formation and quartzitic hard rocks. The hydrological set up and the groundwater occurrence is further influenced by the Delhi ridge which is the northernmost extension of Aravalli mountain consists of quartzite rocks and extends from southern parts of the territory to western bank of Yamuna for about 35 kilometers. The alluvial formations overlying the quartzitic bedrock have different nature on either side of the ridge. The Yamuna flood plain contain a distinct river deposit. The nearly closed alluvial basin covering an areas of about 48 Km² is occupied by alluvium derived from the adjacent quartzite ridge.

5 DIFFICULTIES OF THE AREA

Ground water is one of the major sources for water supply in Delhi where ground water contributes to substantial quantity of supply. Especially in new development areas ground water is largely being utilized as a drinking water resource, mainly because of the insufficiency of the Yamuna water share for Delhi. Ground water collects in the aquifers over thousands of years through infiltration and ground water flow recharge. A particular amount of ground water is replenished regularly through rainwater infiltration. Sustainable use of ground water would have been preferred where withdrawal of ground water keeps pace with the rate at which it is replenished through recharge. But faster withdrawal rates has lead to fall in water table and finally depletion of ground water. As the recharge in the area is considerably reduced due to increased urban activities and not much of land is available for implementing any other artificial recharge measure.

6 IMPLEMENTATION OF THE SCHEME

Before the implementation of rainwater harvesting system, the following checklist was critically examined:

Technical feasibility
* Rainfall and catchment area is sufficient to meet the demand
* Design is appropriate and easy to maintain
* Material is locally available
* Skill is readily available

Social and economic feasibility
* There is a real felt need for better water provision
* Design is affordable and cost effective
* Community is enthusiastic and willing to be fully involved

Environmental feasibility and health
* Rainwater harvesting to improve both the quality and quantity of the available water
* It will have a positive impact on the user’s health

Alternatives
* All other alternative means of water provision were investigated but none was found suitable
The climate of the Delhi region is semiarid type, with three well defined seasons. The cold season begins at the end of November, and extends to in early July and continues up to September. The hot summer extends from the end of March to the end of June. The temperature is usually between 21.1° C to 40.5°C during these months. Winters are usually cold and night temperatures often fall to 6.5°C during the period between December and February. The average annual temperature recorded in Delhi is 31.5°C based on the records over the period of 70 years maintained by the Meteorological Department. About 87% of the annual rainfall is received during the monsoon months June to September. On an average, rain of 2.5 mm or more falls on 27 days in a year. Of these, 21.4 days are during monsoon months.

The six residents of the building, like any other family in the area, faces a shortage of water of the order of about 50 liters /day /head during normal days which becomes more acute during non-monsoon days. The water table in the area varies from 5.0 to 7.0m. and the aquifer is located in the recent alluvial with impermeable top and bottom. The implementation of scheme encompasses a number of completely separate but interconnected units, having a suitable combined underground storage capacity. Conditions through collection and filtration pit (to make it silt free) and recharge pit. The water table in Pratapganj is found to be at 6.5m in the hand pump of the dwelling unit which goes further down to about 7.0m or beyond during dry season.

As the amount of available rainwater (S) depends on the amount of rainfall (R), the area of the catchment (A), and its run-off coefficient (Cr – taking into account any losses due to evaporation, leakage, overflow and transportation – for a well constructed roof catchment system, it is taken as 0.85). An estimate of the approximate, mean annual run-off from the given catchment is obtained using the following equation:

\[ S = R \times A \times Cr \]

where 
- \( S \) = Mean annual rainwater supply (m³)
- \( R \) = Mean annual rainfall (m)
- \( A \) = Catchment area (m²)
- \( Cr \) = Run-off coefficient

Given that the building has 150 m² of roof top area, the average annual rainfall in Delhi is about 611mm (0.61 m) which is harvested for recharging the aquifer. The Annual water harvesting potential...
from the roof-top of 150 m$^2$ = 150 x 0.6 x 0.85 = 76.5 m$^3$ (76500 liters with a runoff coefficient = 0.85) which is directed to the existing borehole via 4m long, 3m wide and 3m deep "collection and filtration pit" which has been constructed at about 15 m away from the building wall but in the same campus of dwelling unit. The pit is filled with boulders at the bottom followed by pebbles and sand at the top. The roof-top rain water as well as the storm water is channeled through 10 cm diameter pipe to the existing 12m deep bore hole / hand pump which is used here to act as the recharge shaft that ends into the aquifer under gravity flow.

Estimating domestic water demand:

The first step followed in designing the rainwater harvesting system was to consider the annual household water demand. To estimate water demand the following equation was used:

\[ \text{Demand} = \text{Water use} \times \text{Household Members} \times \text{Out of 365 days, only 245 days of non-rainy days taken} \]

Therefore, water requirement of the family during the dry period between the two consecutive rainy seasons of 245 days comes out to be equal to 245 x 6 x 50 or 73500 liters. It was observed that the hand pump which remained dry before the monsoon period as the water level go down from 6.5m to beyond 7.0m during dry season, thus making the water pumps defunct brought back the water level at 6.5m or even less so that the pumps started delivering the water. There has been an improvement in the yield of borehole and the groundwater quality.

7 COMPLETION OF THE SCHEME

The rainwater harvesting structure was completed in the year 2007 for a cost of Rupees 4.00 lacs (US$ 8000). Land surface, installations and working is entirely eco-friendly having low impact on environment. The basic infrastructure is expected to last indefinitely and is suitable for any further expansion.

8 RELEVANT DATA COLLECTED

The data on amounts of water collected, problems experienced during the experiment and the information on the extra installations required to meet drinking water standards and their costs, have been collected:

**Amount of collected water:** 36 billion liters

**Problems experienced during the experiment:** The spatial variation in rainfall (averaging 1000 mm or sometimes even lower) not only lowers the water level in river Yamuna which acts as a source of aquifer recharge but also poses problems in collecting rainwater from the roof.
Information on the extra installations required to meet drinking water standards and their costs: Accepted standards of potable water would require additional surface installation such as settling tanks of 90 m³ together with chlorination / UV radiation treatment plants would cost Rupees 70,000 (US$ 1750).

9 EXAMPLES OF OTHER SUCCESSFUL ROOFTOP HARVESTING SYSTEMS IN NEARBY AREAS WITH SHALLOW AQUIFERS

Example 1 - comparative study of water level map of 1960 and 2002 shows in Preetvihar the water level which was at 0 to 2m below ground level has gone down to 5 to 10 m. The area falls in the flood plain of Yamuna, so the intake capacity of recharge structures will be low in shallow water table condition. Hence in Preetvihar where the ground water level is up to 10m rainwater harvesting can be taken up.

Example 2 - Based on the available hydrogeological conditions and data, the roof-top rain water conservation through injection technique was found to be most suitable at Kishangarh in East Delhi where land availability was limited due to very high population density and the aquifer was 12m deep and overlain by the impermeable strata.

10 DETAILS ON SUCCESS AND BARRIER FACTORS

The above two successful cases belong to congested areas of Delhi where not much of land is available for rainwater to infiltrate due to very high population density (900 persons / Km²) and thus with roof top water harvesting system it has been possible to ensure a limited additional regular water supply in the area during dry season. However, the only barrier or short coming is that it attracts large initial capital expenditure and requires additional surface installations for chlorination / UV radiation treatment plants for making the collected water acceptable standard potable water. In addition, collection and filtration pit also requires periodical cleaning after rainy season.

11 F.A.Q. ON SUCCESSFUL COMPLETION OF THE PROJECT

On successful completion of the above roof-top rainwater harvesting project in Pratapganj, the following questions have been received and replied:

*What is rainwater harvesting?*
It simply means catching and holding rain where it falls and using it. You can store it in tanks or you can use it to recharge groundwater.
**Does it work?**
Yes.

**Can I harvest rain in my own house?**
Yes you can. Structures to harvest rain require little space. A dried bore well, a row of soak pits or a tank—concealed below the ground—are all that you need. The open spaces—rooftops and ground—can be used as your catchment (surface to catch rain).

**How much will it cost?**
It varies, depending on the area of your roof and other structures that you will use to harvest rain. But rainwater harvesting does not require major construction work, so the expenses suit most of our pockets.

**Who will it benefit?**
You. Your groundwater will be recharged. But as groundwater moves, your neighborhood will gain too. So for best results, get all your neighbors to become rainwater harvesters as well.

**What will be the quality of water?**
Do not let water with sewage or other dirt flow into your recharge pits. This is why the cleanest rainwater is from our rooftops.

**Does it require a lot of maintenance?**
Once or twice a year, at very little cost. This is about building our relationship with water and with the environment. Harvest rain. Be aware the value of each raindrop.

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**12 SOCIO-ECONOMIC AND ENVIRONMENTAL IMPACT**

The conserved water during monsoon season augmented the groundwater level by at least 0.05m for enabling the stakeholders of the house to use it during non-monsoon period through existing hand pump. This has improved their quality of life otherwise they were using polluted water for their daily needs thus affecting their health. Such local initiatives have reduced the dependence on imported water. The conserved rain water was found to be bacteriologically safe, free from organic matter, soft in nature and improved the groundwater quality through dilution, specially for fluoride (fluoride came down to less than 1.5 ppm from 2.5 ppm which is the safe limit prescribed by the WHO for drinking water). Moreover, the infrastructure is also environment friendly and does not generate any waste product.

**13 BENEFITS/ DRAWBACKS**

The following benefits are accrued from the scheme:

1. Limited additional regular water supply in the area during dry season.
2. Land surface, installations and working entirely unaffected.
3. The basic infrastructure is expected to last indefinitely and is suitable for any further expansion.
4. However, the only drawback or short coming is that it attracts large initial capital expenditure and requires additional surface installations for chlorination / UV radiation treatment plants for making the collected water acceptable standard potable water. In addition, collection and filtration pit also requires periodical cleaning after rainy season.
14 INITIATIVES FROM THE GOVERNMENT OF INDIA

Since June 2001, the Ministry of Urban affairs and Poverty Alleviation has made rainwater harvesting mandatory in all New Buildings, Residential Societies, Institutions, Hotels, Industrial Establishments and Farm Houses located in the notified areas in and around New Delhi with a roof area of more than 100 sq m and in all plots with an area of more than 1000 sq m, that are being developed and if not adopted within the specified period as given above, the existing tube wells in the premises would be sealed and would also attract penal action under section 15 of the Environment (Protection) Act, 1986. The notification, if followed in the right spirit would help in building up necessary storage for assured water supply in future to overcome the problem of water shortages in different parts. The CGWA has also banned drilling of tubewells in notified areas.

15 CONCLUSIONS AND RECOMMENDATIONS

With the success met in implementing the roof top rain water harvesting in Kishanganj in 2004, the way was now clear to implement it in the Pratapganj and other areas of National Capital Region. The roof-top rain water conservation through injection technique has successfully being implemented and found to be most suitable at Pratapganj in East Delhi where land availability was limited due to very high population density and the aquifer was deep and overlain by the impermeable strata. The water level depletion during summer is very common problem throughout the country specially the mega cities with rapid urbanization. With encouraging results from the present experimentation, it is recommended that the scheme be extended for implementation in Group Housing Societies where large rooftop surface area will be available to conserve rain water so that it could be tapped judiciously when needed. It is need of the hour as well as the Government before we reach the last drop of the water.

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